Introduction to Intelligent Systems in Traffic and Transportation

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ABSTRACT

Urban mobility is not only one of the pillars of modern economic systems, but also a key issue in the quest for equality of opportunity, once it can improve access to other services. Currently, however, there are a number of negative issues related to traffic, especially in mega-cities, such as economical issues (cost of opportunity caused by delays), environmental (externalities related to emissions of pollutants), and social (traffic accidents). Solutions to these issues are more and more closely tied to information and communication technology. Indeed, a search in the technical literature (using the keyword "urban traffic" to filter out articles on data network traffic) retrieved the following number of articles (as of December 3, 2013): 9,443 (ACM Digital Library), 26,054 (Scopus), and 1,730,000 (Google Scholar). Moreover, articles listed in the ACM query relate to conferences as diverse as MobiCom, CHI, PADS, and AAMAS. This means that there is a big and diverse community of computer scientists and computer engineers who tackle research that is connected to the development of intelligent traffic and transportation systems. It is also possible to see that this community is growing, and that research projects are getting more and more interdisciplinary. To foster the cooperation among the involved communities, this book aims at giving a broad introduction into the basic but relevant concepts related to transportation systems, targeting researchers and practitioners from computer science and information technology. In addition, the second part of the book gives a panorama of some of the most exciting and newest technologies, originating in computer science and computer engineering, that are now being employed in projects related to car-to-car communication, interconnected vehicles, car navigation, platooning, crowd sensing and sensor networks, among others. This material will also be of interest to engineers and researchers from the traffic and transportation community.

KEYWORDS

intelligent transportation systems, traffic modeling, traffic simulation, advanced traveler information systems, traffic control, traffic assignment, traffic management, route choice, routing, route guidance, driver assistance systems, car to car communication, artificial intelligence, machine learning, reinforcement learning, swarm intelligence, multiagent systems

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Preface

Over the last decades, there has been an increasing interest in aspects that lie in the intersection of computer science and traffic engineering. This is not surprising: in the introductory chapter of this book we provide several figures about the importance of transportation to the economy and daily life of the modern citizen, especially in urban environments. Just to mention one of those figures, congestion is now mentioned as one of the major problems in various parts of the world. This naturally brings in the issue of optimization, a subject that is dear to computer scientists. Besides, the diffusion of the Internet of Things and Mobility Internet promises to reduce the gap between computer engineering and traffic engineering. Indeed, it is predicted that we will see a surge in shipments of car wi-fi systems. This opens up the possibility for completely new ways to manage mobility of people and goods, as well as to optimize traffic flows, just to mention two obvious examples of new possibilities. In fact, the so-called smart mobility is one of the pillars of research projects related to smart or intelligent cities. Smart mobility aims at connecting the use of technology (Internet, sensors, mobile devices) to gather and integrate information in order to improve the efficiency of the transportation system (e.g., reducing congestion, optimize infrastructure, reduce costs, accidents, emissions, and increase the comfort of the user).

Given this panorama, the goal of the present book is to give a broad introduction into the relevant concepts related to traffic and transportation systems, targeting researchers and practitioners from computer science and information technology.

READERSHIP AND ROADMAP

This book is directed towards computer science students, practitioners, and researchers who want to learn the basics on traffic systems and how intelligent methods from AI and other computer science areas can be used for solving traffic-related problems. Understanding the book content requires basic computer science knowledge. On the one hand, the book is mainly interesting for people without deeper knowledge on traffic systems. For these, Chapters 2, 3, and 4 give the introduction to concepts related to traffic infrastructure, demand, and demand assignment, respectively. Chapter 5 deals with the, often relegated, issue of acquisition of traffic data.

On the other hand, this book might also be interesting for people with a background in traffic engineering, who are interested in getting a perspective from the computer science and information technology (IT) points of view, especially when it comes to ITS (Intelligent Transportation Systems), which we introduce in Chapter 1. Besides, these readers may also find, in the last chapter, a discussion of recent trends and use of new technologies that appear with the possibility of electro-mobility and car-to-car communication.

Chapters 6, 7, and 8 are directed to both computer scientists and traffic engineering researchers and practitioners; they discuss issues that include microscopic and agent-based modeling and simulation, intelligent control of traffic signals, and in-vehicle route guidance, among others.

LITERATURE COVERING RELATED AREAS

The present textbook focuses on vehicular traffic. Despite this topic being closely related to others, such as simulation of pedestrian movements, logistics, public transport, air traffic control, and others, we intentionally do not cover these. The interested reader is referred to textbooks such as Morlok [1978] and Sussman [2000], or survey papers that focus on particular issues, such as agent-based management of logistics [Davidsson et al., 2005] or multiagent approach to manage air traffic control Agogino and Tumer [2012].

PERSONAL PRONOUNS

We found that the sole use of "she" (an obvious choice given the authorship!) would be unfair. Therefore we use both "he" and "she" in a more or less random way.

Ana L.C. Bazzan and Franziska Klügl
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Luiz H.D. Souza implemented the simulation of the circular road in SUMO, which was used to illustrate the concepts of shock wave and fundamental diagram. Gabriel de O. Ramos and Alessandro D. Vecchia have provided manual counting of vehicles.

Icons from OpenClipArt (`http://openclipart.org/`) were used in Figures 1.1 and 2.4.

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List of Symbols

a	acceleration
C	capacity
Δ_t	time interval
k	density
K	countings (of number of vehicles)
N_x	number of vehicles (vehicle count) at t_i in Δ_x
N_t	number of vehicles (vehicle count) at x_i in time interval Δ_t
q	flow
s	distance
v	speed
V	volume
$\bar{v}$	average speed
θ	offset (progressive systems)
t	time
T	number of trips